Profiles of Topics and Authors of the International Symposium on Multiple-Valued Logic for 1971-1991*

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Abstract

We consider the growth of multiple-valued logic over the 21 year period from 1971 through 1991, as indicated by papers in the International Symposium on Multiple-Valued Logic. Of specific interest are 1) trends in research topics. This includes patterns of growth and decline. We also consider 2) the demographics of the contributing authors. This includes the distribution of authors by country, the percentage of authors who are new, percentage of new authors who return, and the distribution of authors by affiliation (academia, industry, and government). To derive these statistics, we developed a database of papers, authors and topics. This can be used, for example, to do library searches or to assign papers to referees.

1. Introduction

It has been thirteen years since the last analysis of papers in the *Proceedings of the International Symposium on Multiple-Valued Logic* (ISMVL). In 1979, Ginzer and Butler [2] presented an overview of the first eight years of this symposium. They discussed the international composition of the organization and percentage of first-time authors. We are now able to examine the first 21 years of ISMVL. The present wide availability of database programs allows us to collect and present data in ways that were impractical thirteen years ago. With these tools, we investigate the growth and vitality of multiple-valued logic (MVL) and examine whether ISMVL is serving the needs of its members.

2. Profile of Papers in ISMVL

A simple but effective way to measure growth is to count the number papers published per year. This ranges from a low of 18 in 1971 and 1972 to a high of 68 in 1989. A general upward trend in the number of papers is shown in Fig. 1.

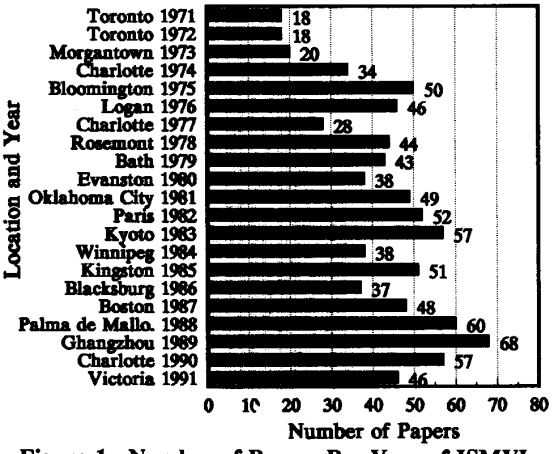

Figure 1. Number of Papers Per Year of ISMVL.

Growth in a discipline is also measured by an increase in the number of areas in which it is applied. Therefore we analyze papers by topic. Papers are first categorized by *major topic*. There are eight major topics, each analogous to a general session category given in the Proceedings. Fig 2. shows numbers of papers in each major topic by year for the past 21 years. A second type of topic is the *minor topic*. The minor topic represents specific areas within a major topic. While the major topic provides a unique classification that tracks broad areas, the minor topic is more specialized and is not unique. Minor topics can span major topics. For example, the minor topic "minimization" occurs under the major topics of fuzzy logic, logic design, and circuits. Every paper is assigned at least one and up to four minor topics. Minor topics are also the best indi-

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14. ABSTRACT

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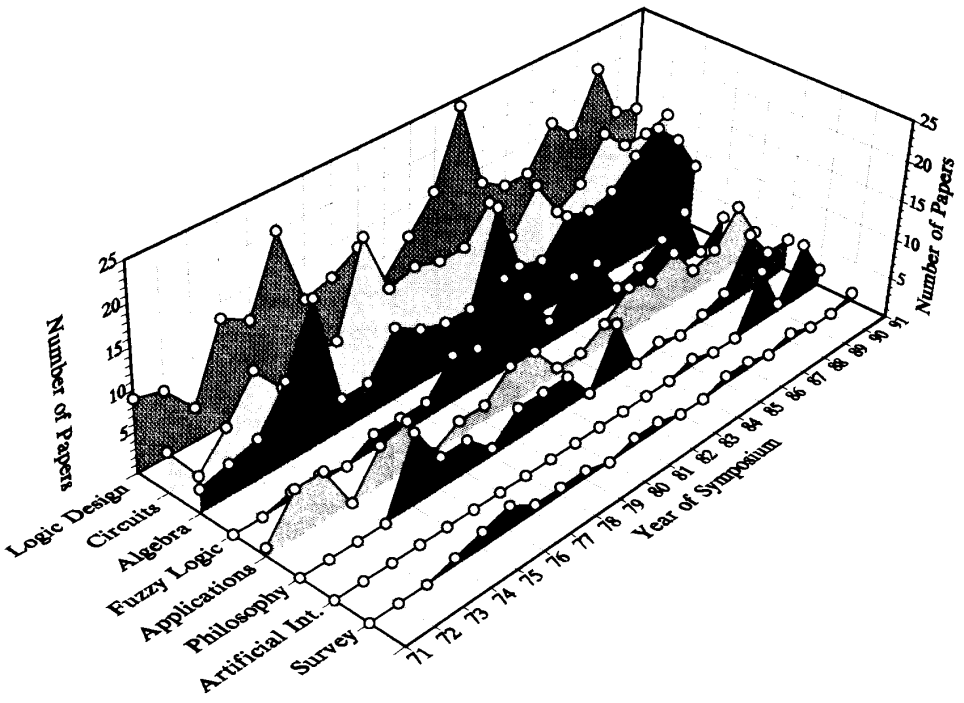

Figure 2. Number of Papers by Major Topic by Year.

cators of increasing breadth, as researchers explore new areas, integrate MVL into other disciplines, and carry theoretical results into practical applications. Appendix I lists the 416 minor topics. Some such as "completeness" cover many areas and are widely used. Others such as "Oracle" occur in only one paper, but enable researchers to easily locate such papers. Minor topics serve to index the database used to generate the data presented here; the database contains 902 papers, 732 authors, and 1600 author/paper pairs.

Fig. 3 shows the number of papers per year in selected minor topics. We chose these specific minor topics because each one represents a special characteristic, for example, an increase or decrease in research interest. As an illustration, in "approximate reasoning" eight of the nine papers have been published in the last seven years. Similarly, over half the papers on "clones" and "expert systems" have been submitted in the last five years. These represent growing areas on interest. Biological computing has entered the list of minor topics in the last four years and illustrates a new area.

Our results also show topics that experienced a loss of interest. For example, "hazards" and "microprogramming" have seen a decline. For both topics, no paper has been published in the last five years, and there has been diminishing interest in the years just prior to that.

Some topics, such as fuzzy (logic), illustrate another characteristic. Certain topics exist as both major and minor topics. That is, a topic may be the subject of a paper that falls primarily into another major category. For example, an application or circuits paper, may utilize fuzzy logic although not making a direct contribution to it. Another measure of health is the diversification of MVL theory in practical applications. We measure this in two ways, the number of applications papers and the number of different applications topics that MVL papers address. We note from Fig. 2, that there are a substantial number of applications papers. A total of 68 applications papers have been published. These papers cover approximately 50 distinct topics, including, for example, document retrieval and security.

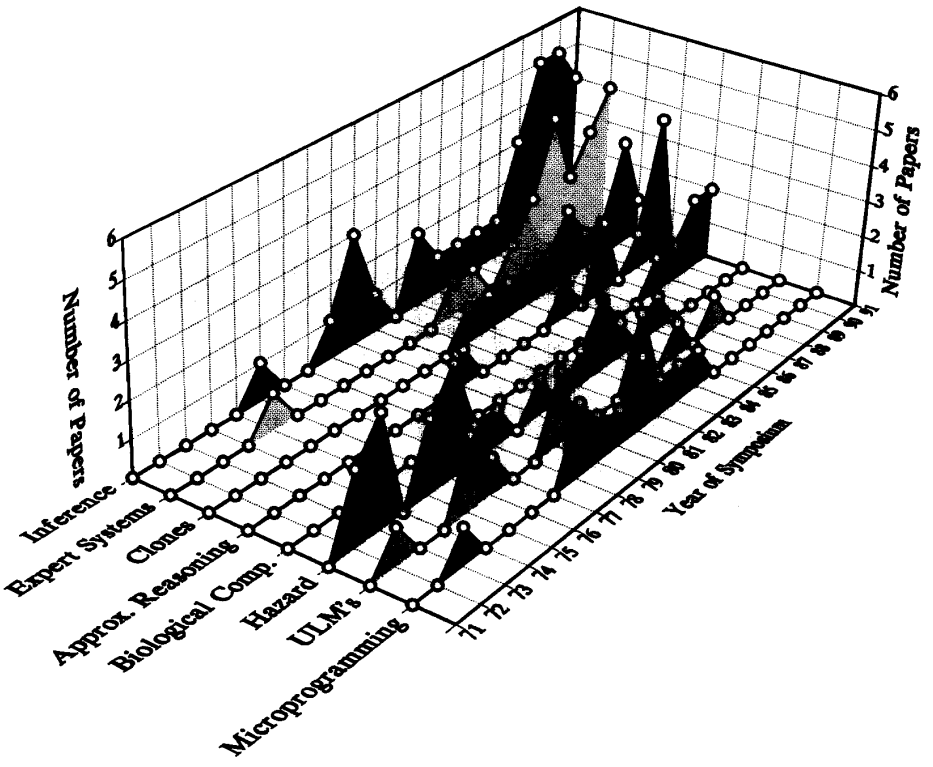

Figure 3. Number of Papers Per Year in Selected Minor Topics.

3. Profile of ISMVL Authors

We next consider the contributors. Fig. 4 shows the number of authors per year. We note that there has been an upward trend over the past 21 years.

Of special interest is the number of researchers who contribute a paper to the ISMVL for the first time. The ability to attract new researchers is an important measure of the vitality of any discipline. Fig. 4 shows the number and percentage of all authors who were new contributors for each year. For the first symposium, 100% of the authors are new. The percentage of new authors in the second through fifth ISMVL's was between 64% and 71%. For succeeding symposia, this percentage decreased slightly, but has remained generally high. The lowest percentage was in 1977 at 37% and the high was 59% in 1988, with an overall average of about 50%. Related to the new author issue is the ability of the symposium to retain the interest of these first time authors. We, therefore, examined the number of such authors who contributed a paper in some subsequent year. Fig. 4 also shows this data. The largest number of returnees occurred from 1983. Of the 54 new authors, 25 returned in later years. The next largest number, 19, occurred from 1971. As expected, the percentage of new authors who return drops for more recent symposia, since there are fewer opportunities for attendance. The overall average, 32%, shows a healthy continuing interest in MVL.

Fig. 5 shows a histogram of productivity of ISMVL authors. Counting authors with many papers gives a sense of how many have a strong commitment to MVL. In the past 21 years, 23 authors have contributed more than 10 papers each, and one author has contributed 32. As expected, many authors, 481, have contributed just one paper.

Fig. 6 shows an interesting, related trend. Plotted here is the number of authors divided by the number of papers per year. This is not the average number of authors per paper because of authors who have more than one paper that year, but it is close. There is a general upward trend. As multiple-valued logic has matured, there are fewer single authors and more group activity. The passage of time has allowed the formation of research partnerships, assimilating new authors into

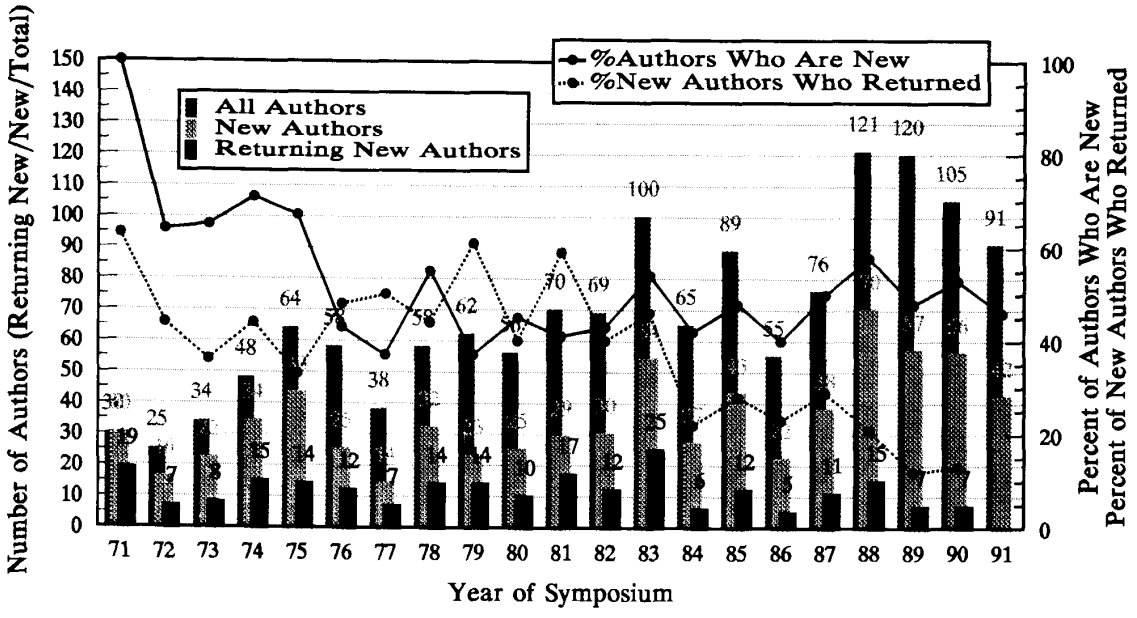

Figure 4. Number of Authors and Number and Percentage of New Authors.

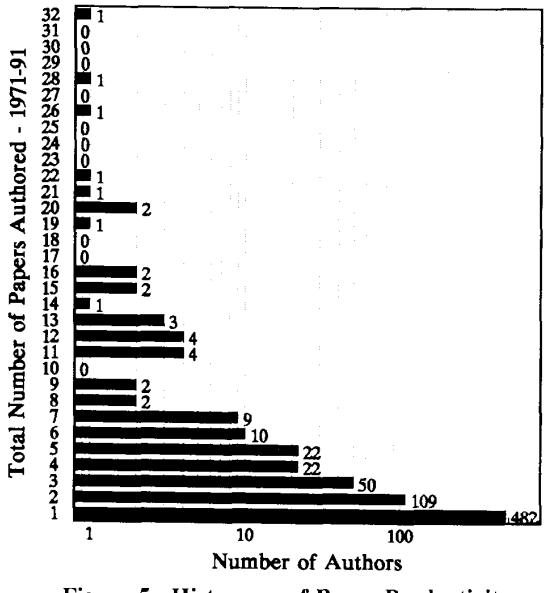

Figure 5. Histogram of Paper Productivity.

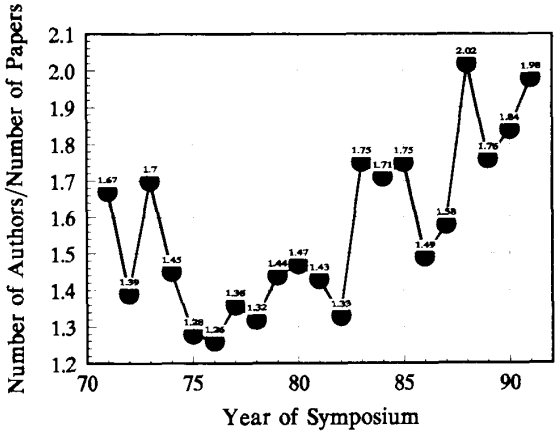

Figure 6. Number of Authors/Number of Papers.

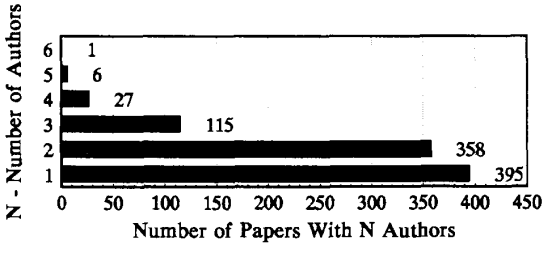

Figure 7. Histogram of Author Multiplicity.

the research community. We believe this is another indicator of growth and evolving author participation.

Fig. 7 shows the distribution of papers by number of authors for the past 21 years. The vertical axis shows how many authors collaborated on a paper, while the horizontal axis shows how many papers there are with

Year / Country	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	Total
Algeria														1								1
Argentina										1										3		4
Australia																			1		1	2
Austria											1	2					2					5
Belgium					2	2	2	3	3			1										13
Brazil												2								3		5
Canada	5	3	6	10	12	12	8	4	5	4	6	6	8	10	11	8	6	14	13	15	17	183
Chile	1	1	2	3	1											1						9
China								1		1	3	3	10	7	17	7	7	15	47	9	2	129
Denmark												1										1
Ecuador										1	1	1	1									4
England				1	4	4		1	12	2	5		2	3	1	2		2	1			40
Finland		3	2	1																		6
France	1		2	2	2	3	4	3	3	4		2		3	4		4	1		3		41
Germany					1	1	3	2	2	1	2	3		2	2	1	4	2	5	4	4	39
Hungary												2	3	3					1	1		10
India				2									1	1								4
Iran																					1	1
Iraq								2				2			2							6
Israel				2	3								1		1							7
Italy												2	3									5
Japan	3	2	3		3	8	7	7	9	8	11	8	39	13	18	10	17	22	23	18	30	259
Korea																				1		1
Mexico																	1					1
Netherlands							1			1	3	2	3		3	2	2	2		2		21
Nigeria										1	1											2
Poland			1	1	6	1	1					2	3	2		2	1			2	2	24
Portugal																				2		2
Saudi Arabia										1	2											3
Singapore																				4		4
South Africa											1											1
Spain						2	2	4	2	2	7	5	1		3	2		26	6	2	4	68
Switzerland				1																		1
Taiwan											1		1									2
USA	20	16	17	25	29	25	10	31	26	29	26	21	24	19	27	20	31	35	18	36	29	514
USSR					1							3							1			5
Yugoslavia														1			1	2	2		1	7
Unknown			1									1							2			4
Total	30	25	34	48	64	58	38	58	62	56	70	69	100	65	89	55	76	121	120	105	91	1434
Year	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	Total

Figure 8. Number of Authors by Year by Country.

that many authors. Single-author papers are the most common, with two-author papers a close second.

4. Profile of the Symposium

From the first symposium in 1971, internationalism has been a hallmark of ISMVL participation. In 1971, authors from five countries (Canada, Chile, France, Japan, and the U.S.) on four continents participated Fig. 8 illustrates the continuing geographic spread of interest, as a distribution by author's nationality. Some interesting observations can be made. In 1971, 67% (20) of authors were from the U.S., with Canada as the second most prolific contributor. In 1991, authors came from 10 countries world-wide. Japan has taken the lead with 33% (30) of the authors, while the U.S. is a close second with 32% (29). Fig. 8 shows the number of authors contributing according to country over the 21 year history of the ISMVL.

A related factor is symposium location. We consider how the location of a conference affects the retention

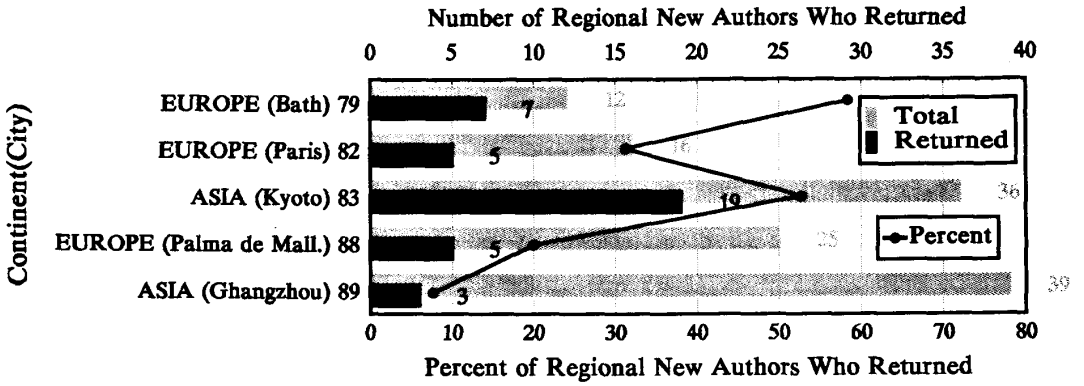

Figure 9. New Author Continuation Data for ISMVL Outside North America.

rate of new authors. Five symposia have been held outside North America - Japan (1983), People's Republic of China (1989), France (1982), Spain (1988), and England (1979). For analytical purposes, we consider the continent of both symposium and authors. At the symposium held in Japan, there were 54 new authors, of which 36 were from Asia. Of these new Asian authors, 19 or 53% have contributed a paper to at least one subsequent symposium. For the conference held in France, there were 30 new authors, 16 of whom were from Europe. Of these, 5 later returned, a retention percentage of 32%. Fig. 9 shows results for all symposia held outside of North America. Although the results are not as clear for the '88 and '89 ISMVL, because of the lack of time an author has had to return, we believe this data shows there is a benefit to the wider geographical distribution of ISMVL.

As another measure of vitality, we consider whether ISMVL attracts researchers from industry and govern-

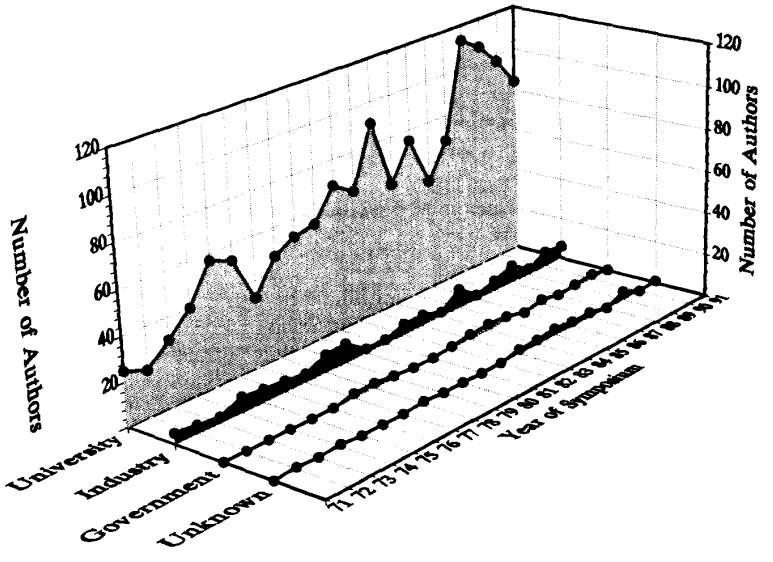

Figure 10. Distribution of Authors by Affiliation.

ment, the primary users of technology, and from academia, the primary source of theoretical advances. Fig. 10 shows the distribution of authors by affiliation. Here, the result is less encouraging. Participation by government and industry averages slightly less than 10% of university participation. This identifies one area where efforts can be made to attract researchers.

5. Concluding Remarks

Our analysis shows both topics for which interest is decreasing, as in "hazards", and those for which it is increasing, as in "expert systems" and "clones". Any growing and evolving discipline will demonstrate both these attributes, as areas cease to be fruitful and new areas of exploration arise.

Over the 21 year history of the symposium, approximately 50% of each year's authors are first time contributors. This was a surprising result of the study of the first eight years; it is still surprising. We also considered the retention rate, an average 32%, as significant and positive.

We investigated to what extent the location of the symposia affects attendance. We expected that a conference in a location tends to attract authors from that location, but questioned whether this would stimulate ongoing interest in ISMVL. Our results show, in varying degrees, an increase in follow-on attendance by these authors. Our results also show the need to attract researchers in industry and government.

The overall conclusion of this study is that multiple-valued logic and the ISMVL which serves as its forum, remain healthy. There continues to be a balance between new authors and long-time contributors. There is progress toward practical applications, and there is a harvesting of the benefits of world-wide locations.

Acquiring the Database

The database is available upon request. It is formatted in DataPerfect, a companion database to WordPerfect. To obtain a copy, send a blank high density 3.5" to either author with a self-addressed flopper mailer envelope. No warranty is made on this database.

Acknowledgments

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APPENDIX I: LIST OF MINOR TOPICS

A/D CONVERTER
ABELIAN
ABNORMALITY PREDICAT
ADDERS
AGGREGATION
ALGORITHMS
ALU
AMBIGUITY
ANALOG
ANALYSIS
APPLICATION
APPROX REASONING
ARCHIMEDEAN
ARCHITECTURE
ARITHMETIC
ARRAYS
ARTIFICIAL INTEL
ASSOCIATIVE MEMORY
ASSOCIATIVITY
ASYNCHRONOUS
ATOMIC ALGEBRAS
AUTO TEST GENERATION
AUTO THEOREM PROVING
AUTOMATA
AUTOMATED DESIGN
AUTOMATED REASONING
AUTOMATIC CONTROL
AXIOMATIZATION
AXIOMS
BALANCED GATES
BARREL SWITCH
BELNAP
BETA-RESOLUTION
BI-DIRECTIONAL
BI-POLAR
BIBLIOGRAPHY
BINARY
BIOLOGICAL ALGEBRA
BIOLOGICAL COMPUTING
BLOCK FUNCTIONS
BOCHVAR
BOOLEAN
BOOLEAN DIFFERENCE
BOOTH
BOUNDARY-SCAN
BUS
CAD
CAM
CANONICAL FORMS
CAPACITOR
CARNAP
CARRY-LOOK-AHEAD
CASCADES
CCD
CELLULAR ARRAYS
CELLULAR AUTOMATA
CHARGE-CONTROL
CHINESE PHILOSOPHY
CHIP ARCHITECTURE
CHIP LAYOUT
CHRESTENSON
CIRCUITS
CLEFTS
CLONES
CLOSURE
CMOS
CODES
COGNITIVE PROCESS
COMBINATIONAL
COMPACTNESS
COMPAR. LOOK-AHEAD
COMPARATIVES
COMPARATORS
COMPLETENESS
COMPLEX NUMBERS
COMPLEXITY
COMPRESSION
COMPUTER DESIGN
COMPUTER SCIENCE APP
CONDITIONAL
CONNECTIVES
CONSISTENCY
CONTAINMENT
CONTRADICTORIAL
CONTROL
CONVERTERS
COPULAS
COST
COSTTABLE
COUNTER
CRYPTOGRAPHY
CURRENT-MODE
CURVE GENERATION
CYCLIC CODES
D-FUZZY
DATA BANK
DATABASES
DE MORGAN
DEBUGGING
DECIDABILITY
DECISION ALGEBRAS
DECISION CIRCUITS
DECISION DIAGRAM
DECISION THEORY
DECISION-MAKING
DECISIVE
DECODERS
DECOMPOSITION
DEDEKIND
DEDUCTION
DEGREES OF TRUTH
DELTA FUNCTIONS
DEMOGRAPHICS
DEMORGAN
DETACHMENT RULE
DETERMINISM
DIAGNOSIS
DIFFERENTIAL CALCULU
DIGITAL SIGNAL PROC
DIRECTED SEARCH
DISCRETE FUNCTION
DISJOINT
DISSOLUTION
DISTRIBUTED SYSTEMS
DIVIDERS
DOCUMENT RETRIEVAL
ECL
EMBEDDING
ENCODERS
ENTROPY
ENUMERATION
EQUALITY
EQUIVALENCE CLASS
ERROR CORRECTING
ERROR DETECTION
EXCLUSIVE OR
EXPERT SYSTEMS
EXPERT-SYSTEMS
FAIL-SAFE
FANOUT-FREE
FAST FOURIER TRANSFO
FAULT DETECTION
FAULT DIAGNOSIS
FAULT MODELLING
FAULT TOLERANCE
FIBEROPTICS
FIBONACCI
FIELD EFFECT TRANSIS
FILTERS
FLIP-FLOP
FLOATING GATE
FLOWCHARTS
FORMAL LANGUAGE
FOURIER
FUNCTION DERIVATION
FUNCTIONS
FUTURE DIRECTION
FUZZY
GAAS
GALOIS
GANGED-LOGIC
GATE ARRAY
GAUSS
GENTZEN
GEOMETRIC
GRAPH THEORY
GROUPOIDS
GROUPS
HAMMING
HARDWARE DESIGN
HARMONIC ANALYSIS
HARR
HASHING
HAZARD
HEDGE-ALGEBRAS
HEIGHT CLASSIFICATIO
HEYTING
HILBERT
HOMOMORPHISM
HORN
HYPEREALS
HYPERPLANES
IDENTITY
IMAGE PROCESSING
IMPLICATION
IMPRECISION
INCOMPLETELY SPECIFI
INDIA
INDISTINGUISHABILITY
INDUCTION
INFERENCE
INFINITE-VALUED
INFORMATION THEORY
INSTRUCTION SYSTEMS
INTEGRAL CALCULUS
INTERCONNECTION
INTERMITTENT FAILURE
INTERRUPTS
INTUITIONIST LOGIC
INVERSES
INVERTERS
INVOLUTION
ION IMPLANTS
ISOTONIC
ITERATION
I2L
JAPAN
JOSEPHSON
KARNAUGH MAPS
KLEENE
KNOWLEDGE-BASED
LAKOFF
LAMBDA RESOLUTION
LAMBDA-RULES
LATCH
LATTICE
LEARNING
LEGAL DECISION MAKIN
LINEAR CODE
LINEAR TREE
LINEARLY SEPARABLE
LINGUISTIC
LIPSCHITZ
LITERALS
LOCAL AREA NETWORKS
LOGIC DESIGN
LSI
LUKASIEWICZ
MAJORITY FUNCTIONS
MAJORITY VOTER
MANAGEMENT ANALYSIS
MARKOV
MASS MEMORY
MATRICES
MEDIUM ALGEBRA
MEDIUM LOGIC
MEMORY
MESFET
MICROPROGRAMMING
MINIMAL
MINIMIZATION
MINKOVSKI
MIX-RADIX
MIXED-VALUE ALGEBRA
MODAL
MODEL THEORY
MODELLING
MODSUM
MODULAR DESIGN
MODULAR LATTICE
MODULAR REDUNDANCY
MODULE
MODULO-ALGEBRA
MODUS PONENS
MOLECULAR COMPUTING
MONOTONIC
MOS
MOSAICS
MULTIPLEXERS
MULTIPLIERS
MVL HISTORY
NATURAL LANGUAGE
NEGATION
NETWORK
NEURAL
NMOS
NON-MONOTONIC
NUMBER SYSTEM
OCKHAM
OMEGA LOGICS
OMEGA VALUED
OPTICAL
OPTICS
OPTIMIZATION
OPTOELECTRONICS
ORACLE
ORTHOGONAL
P-ALGEBRAS
PARADOX
PARALLEL PROCESSOR
PARALLEL PROGRAMMING
PASS-TRANSISTOR
PATTERN GENERATOR
PATTERN RECOGNITION
PERFORMANCE EVAL
PERMUTATIONS
PHI-ALGEBRAS
PI-LOGIC
PIPELINED
PLA
PLAUSIBILITY
PLAUSIBLE REASONING
POSETS
POSSIBILITY THEORY
POSSIBLE WORLD THEOR
POST
PRE-PRIMAL
PREDICATE CALCULUS
PREDICATE LOGIC
PREFERENCE RELATIONS
PRENEXATION
PRESUPPOSITION
PRIMAL
PRIME IMPLICANTS
PROBABILISTIC
PROBABILITY
PROCESSORS
PRODUCTION
PROGRAMMING
PROGRAMMING THEORY
PROLOG
PROPOSITIONAL
PROTOCOL
PSEUDORANDOM NUMBER
Q-ALGEBRAS
Q-FUNCTIONS
QUANTIFICATION
QUANTIFIERS
QUASI-TRANSITIVE
QUERY LANGUAGE
QUOTIENT ALGEBRAS
RACES
RAM
RANKING
REAL-TIME
REASONING
RECURSION
REDUCIBILITY
REDUCTION
REDUNDANCY
REED-MULLER
REGISTERS
REGULAR FUNCTIONS
REGULARITY
RELIABLE
RESIDUE NUMBER
RESOLUTION
RESONANT TUNNEL DIOD
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ROBBINS
ROM
ROOTS
RULE-BASED
SATURATION
SCHMITT
SECURITY
SELF-CHECKING
SELF-DUAL
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SEQUENTIAL
SET LOGIC
SETS
SHALLOW FUNCTIONS
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SIGMA ALGEBRAS
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SUM-OF-PRODUCTS
SWITCH-LEVEL
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SYLLOGISMS
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TRANSITIVITY
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TRANSPORT EQUATIONS
TREES
TRIANGULAR NORMS
TRUNCATED DIFFERENCE
TTL
ULM
UNANIMITY
UNARY
UNATE
UNDECIDABILITY
UNIFORMITY
UNIVERSAL
VARIABLE VALUED
VECTOR
VENN DIAGRAM
VLSI
VOLTAGE-MODE
WALSH
WAVEFORM
ZHANG-HARTLEY
ZORN
5TH GENERATION